Drip Irrigation Technology for Watermelon Crops with IoT-Based Solar Panels for Efficient Use of Energy Resources

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Abstract
Water scarcity and energy inefficiency are major challenges in modern agriculture, particularly for water-intensive crops like watermelon. This study aims to develop a sustainable solution by integrating drip irrigation technology with IoT-based solar panels to optimize water and energy use. The purpose of this research is to design and test a system that uses renewable solar energy and IoT sensors to monitor soil moisture and control irrigation automatically, providing an efficient and environmentally friendly solution for watermelon farming. The methodology involves the development of a prototype system powered by solar panels and equipped with IoT sensors for real-time data collection and system management. The findings demonstrate that the solar-powered IoT drip irrigation system significantly reduces water consumption and energy costs compared to conventional irrigation methods, ensuring efficient water use while operating off-grid. The practical implications of this study suggest that this integrated system can be scaled for large-scale farming operations, improving crop yields and contributing to sustainable agricultural practices. The results highlight the potential of combining renewable energy, IoT, and modern irrigation techniques as a viable solution to address global challenges of water conservation, energy efficiency, and sustainable farming.

1. Introduction

Soil moisture is important in plant growth because it affects the availability of water and nutrients that are absorbed by plant roots (Hudhoifah & Mulyana, 2024). Inappropriate soil moisture can cause wilting in plants, inhibit growth, and even cause plant death (Effendi et al., 2020). Therefore, monitoring therefore, monitoring soil moisture is important in modern agriculture to ensure that plants grow optimally especially in watermelon plants. Watermelon plants requires soil moisture between 70-80% field capacity for maximum growth and fruit production. Humidity that is too low causes water deficiency, inhibition of nutrient absorption, and wilting of the plant, while too high moisture reduces root aeration. plants, while moisture that is too high reduces root aeration, increases the risk of disease infection, and reduces fruit quality.

Soil drought can be a serious problem in agriculture in drought-prone areas that are prone to drought (Mahfud & Farhan Anshori, 2023). Plants growing in soil that is too dry will be stressed and experience difficulty in growing, which can hamper crop yields (Gata & Tanjung, 2023). This problem is exacerbated by global climate change which is causing extreme weather and irregular rainfall patterns (Setiawan & Anggraen, 2019).

Several previous studies were similar and became the basis for this making a prototype, namely (Rindy Saputra et al., 2023) Components used in an IoT-based automatic monitoring and watering system for plants Mustard greens includes NodeMCU8266 as a microcontroller for processing data and connect the system to the internet. (Suprasetyo et al., 2023) System Automatic watering and monitoring for oil palm seedlings using Fuzzy Sugeno method for decision making based on sensors soil moisture and temperature, as well as controlling the water pump automatically. (Aisyah et al., 2024) This system automates watering chili plants uses ESP32 microcontroller and RTC digital clock for schedule watering. Capacitive Soil Moisture Sensor controls water pump at 60% and 80% humidity, the DHT22 sensor monitors air temperature and humidity as well controls the lights and sprayer nozzles, and the Soil pH Sensor ensures Optimal pH. (Amwriter, 2024) Automatic watering system using sensors soil moisture to detect moisture and control the pump. (Yonathan, 2023) This smart irrigation system uses the ESP-8266 microcontroller as a central unit connected to various sensors and actuators to monitor and control the watering process.

The main differences between the Author's research on "TECHNOLOGY DRIP IRRIGATION ON WATERMELON PLANTS WITH SOLAR PANELS IOT BASED FOR EFFICIENT USE OF WATER AND RESOURCES ENERGY POWER" with other research lies in the integration of panel technology solar to provide renewable energy that supports drip irrigation systems. Meanwhile, other research focuses more on the use of microcontrollers and sensors for monitoring soil moisture, temperature, and environmental conditions for automatic control of water pumps and plant watering, Author's research emphasizes energy efficiency by utilizing solar panels as the ultimate resource for IoT based irrigation systems. This approach is not the only one optimize water use with drip irrigation technology but also reducing dependence on conventional energy resources, making it a more sustainable and efficient solution for agriculture.

Automatic watering systems are becoming increasingly popular in Agriculture modern (Muhammad Nur et al., 2020). This system allows farm owners to provide feed on a scheduled and consistent basis, which is very important for growth (Koehuan et al., 2024). By using IoT technology, Automation systems can be set and monitored remotely via the app or online platforms. The integration of solar panels into the system is not only improve authorship and operational efficiency, but also reduce costs long-term operations by eliminating dependence on electricity from general network(Purboseno et al., 2023).

The proposed web application will utilize soil moisture sensors that connects to an IoT device, such as an ESP32 or NodeMCU, to measure real-time soil moisture. The collected soil moisture data will sent to the server using the HTTP communication protocol (Poso et al., 2023). Users can then access the web application via any device connected to the internet, such as a smartphone or computer, to monitor soil moisture on their agricultural land. The web application will also provide notification feature to notify users if soil moisture is outside desired range, so they can take that action necessary (Pratama Ginting et al., 2023).

By using a web application for monitoring soil moisture, Farmers can overcome this problem. The web application allows users to monitor soil moisture remotely via an internet connection. This matter providing greater flexibility for farmers to monitor conditions their land without having to be in the field. Additionally, web applications can also stores historical soil moisture data, enabling detailed analysis better aware of trends and patterns that may influence water needs plant.

1.1 Literature Review

The proposed prototype for soil moisture monitoring web application on an IoT-based drip irrigation system will use the ESP32 microcontroller as the control center. The ESP32 was chosen because of its inbuilt ability to manage Wi-Fi connections and transmit data wirelessly, making it suitable for applications that require communication with a web server for applications that require communication with a web server. The ESP32 will connect to the soil moisture sensor and any other sensors required, such as the temperature and humidity sensors. The data captured by these sensors will be sent to the web server using the POST method. to the web server using the POST method.

The ESP32 will be responsible for retrieving data from the soil moisture and other sensors, then sending it to the web server soil moisture and other sensors, then send it to the web server for further processing for further processing. This microcontroller will connect to any Wi-Fi network network available in the vicinity, allowing direct transmission of data to the web server. In addition, the ESP32 will also play a role in managing power, ensuring that this prototype can operate efficiently and authoritatively without requiring constant attention from the user.

To send soil moisture data to the web server, the prototype will use the POST method. This method allows data to be sent as part of an HTTP request, which can then be processed by the web server. The data sent will contain information about soil moisture, measurement time, and possibly also data from other sensors such as temperature and humidity. The server server will receive this data and either store it in a database or perform additional analysis according to the needs of the soil moisture monitoring application.

2. Research Methods

This study employs a system development and experimental approach to design and evaluate an IoT-based solar-powered drip irrigation system aimed at optimizing water and energy use for watermelon farming. The methodology consists of the following key steps:

2.1 Prototipe Design

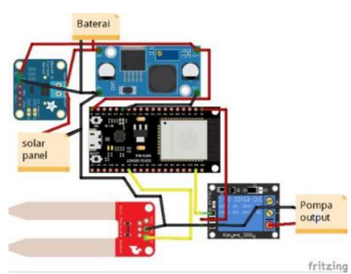

Fig. 1 Schematic Design

Schematic design process using fritzing software. The schematic design of the tool uses 9 components of the tool, initially, the solar panel will generate electricity which will be passed by ina219 to measure the voltage that into the battery and the current entering the battery, so that farmers get information whether the solar panel is working properly, after being measured by ina219, Volt and Ampere information signals will be sent to esp32 through I2C communication namely the Scl and Sda pins, which are found in gpio 21 and 23, besides ina219, the LCD also communicates using I2c to display the information communicates using I2c to display humidity information and the solar panel condition. The Soil Moisture sensor is connected to the ADC pin of Gpio 34. is connected to Gpio 4 on esp32 to turn the pump on and off pump.

2.2 Implementasi prototype

Implementation of a web application for monitoring soil moisture in an IoT-based drip irrigation system drip irrigation system based on IoT in Technopark Park, Technokrat University of Indonesia. will provide various benefits for park managers and visitors. The use of this application will allow park managers to monitor soil moisture conditions in real-time and take necessary actions to maintain plant health. necessary to maintain plant health. In addition, park visitors can also can utilize the information provided by the app to understand more about the plant cultivation carried out in the garden.

Fig. 2 TeknoPark Page

2.3 Diagram Drip Irrigation Block

An IoT-based drip irrigation system designed for watermelon crops, integrates solar panels for efficient use of water and energy resources. energy resources. This system consists of several main components, namely HP/Laptop, internet, server, WiFi modem, ESP32, Solimoisture sensor, INA219 sensor, and pump. HP/Laptop serves as a user interface to control and monitor the system via the internet that connects the device with the monitor the system via the internet that connects the device with the server. The server stores and processes the data received from the ESP32, which collects information from soil moisture sensors (Solimoisture) and current and voltage sensors (INA219).

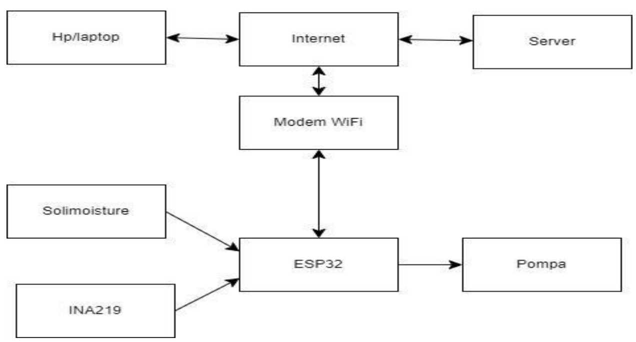

Fig. 3 Drip irrigation Block Diagram

ESP32 is the control center that regulates the flow of water through the pump based on soil moisture data. Energy usage data from the solar panel is monitored by the INA219 sensor and sent to the ESP32 to ensure energy efficiency. A WiFi modem connects the ESP32 to the internet, allowing data to be sent and received in real-time. This system allows users to remotely monitor and control irrigation, ensuring efficient use of water and optimization of energy resources coming from the solar panels.

3. Result and Discussion

This test involves three main aspects, namely testing the sensor INA219 sensor to measure the voltage and current from the solar panel to the battery, testing the soil moisture sensor (soilmoisture), and web testing to monitor and control the system in real-time. Each test was conducted separately to ensure each component functions according to specifications and can work well in an integrated system.

Testing the INA219 sensor aims to ensure accuracy in measuring voltage and current generated by solar panels before being stored inside battery. It is important to monitor the efficiency of solar energy use and ensure sufficient power to operate the irrigation system. Furthermore, Soilmoisture sensor testing is carried out to measure soil moisture directly accurate, which is the basis for controlling water flow through irrigation pumps. Web testing involves assessing the user interface and system capabilities to monitor and control irrigation remotely via the internet, ensure that the data sent and received is real-time and can be reliable. The results of each test are as follows:

3.1 INA219 testing

Testing of the INA219 sensor is carried out to measure voltage, current and power generated by solar panels in an IoT based drip irrigation system. This testing was carried out at various times from 09:00 AM to 3:00 PM with results showing variations in voltage and current throughout the day. At 09:00 AM, the measured voltage is 18V with a current of 0.834A, producing power 15 watts. The voltage and current increase until they reach their peak at 12:00 PM and 1:00 PM with a voltage of 20V and a current of 1.3A, producing power of 26 watts. This data shows that solar panels operate most efficiently at during the day when the intensity of sunlight is highest.

Table 1. Testing of the INA219 sensor

Num.	Time	Voltage (V)	Current (A)	Power (Watt)
1	9:00 AM	18	0,834	15
2	10:00 AM	19	0,968	18
3	11:00 AM	20	1,1	22
4	12:00 PM	20	1,3	26
5	1:00 PM	20	1,3	26
6	2:00 PM	19	1,1	22
7	3:00 PM	18	0,897	16

As time goes by, at 2:00 PM and 3:00 PM, the voltage and current output begins to decline again. At 2:00 PM, the voltage drops to 19V with a current of 1.1A produces 22 watts of power, and at 3:00 PM, the voltage drops further to 18V with a current of 0.897A producing 16 watts of power. These test results show how solar panel performance varies throughout the day according to the intensity of sunlight. This information is important to understand energy use patterns and optimize irrigation systems in order can work efficiently all day long.

3.2 Soil moisture sensor testing

Soil moisture testing is carried out to monitor changes in levels water in the soil at various times throughout the day. Measurement starts at at 9:00 AM with a soil moisture level of 80%. As it goes time, soil moisture gradually decreases. At 10:00 AM, humidity recorded at 79%, and continued to decline until it reached 76% at 12:00 PM. This decrease can be caused by increasing temperature and light intensity The sun causes water to evaporate from the soil.

Table 2. Soil Moisture Sensor Testing

Num.	Time	Soil Moisture(%)
1	9:00 AM	80
2	10:00 AM	79
3	11:00 AM	77
4	12:00 PM	76
5	1:00 PM	70
6	2:00 PM	60
7	3:00 PM	55

At 1:00 PM, soil moisture dropped more significantly to 70%, and the decline continued until it reached 55% at 3:00 PM. This data indicates that the soil experiences significant dryness during the day, which affects water availability for plants. This information is important for irrigation system, because it can be used to determine the time and duration optimal watering. By monitoring soil moisture in real-time, the irrigation system can be set to activate the water pump when there is humidity reaches a certain critical point, ensuring the plant still gets enough water all day.

3.3 Web Testing

Web testing of IoT based drip irrigation system with solar panels shows that the implemented features function well as expected. On the web dashboard, users can by easily change the duration of water spraying. When the "Edit Duration" button is clicked, users can enter new values which are then saved and applied to the system, ensuring that the spray duration can be adjusted as needed watermelon plant.

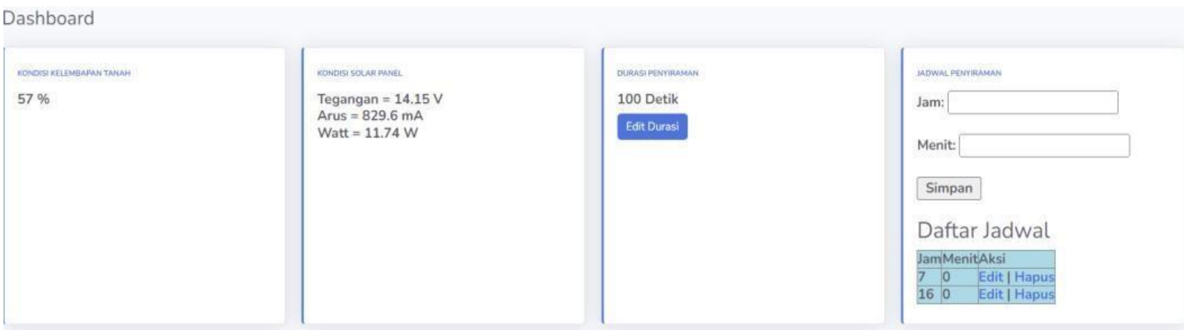

Fig. 4 Web Testing Results

In addition, the irrigation scheduling feature has also been tested with good results satisfying. Users can add new schedules by entering times desired in the "Hour" and "Minute" columns then press the "Save" button. Existing schedules can be changed or deleted via the "Edit" button and "Delete" is available in the schedule list. Soil moisture monitoring function and The condition of the solar panels is also working well. Soil moisture data is displayed in percentage, while the condition of the solar panel shows voltage (V), current (mA), and the power (W) produced. This test proves that the system The web can monitor and control all aspects of irrigation effectively and efficient.

3.4 Prototype Implementation to Partners

Collaboration and active involvement of students in the fertilization process. Such manual processes make it possible to directly monitor conditions plants and soil, and make necessary adjustments to increase fertilization efficiency. Proper and efficient implementation of fertilizer is one of the key factors in achieving good harvest results and sustainable.

Fig. 5 Implementation of Fertilizer and Plants

In the picture above, you can see the process of applying fertilizer to plants on the land agriculture.. This activity shows how fertilizer is applied manually to ensure adequate nutrition for plants. This fertilizer is important to increase the growth and yield of watermelon plants on the land the. This technique also ensures that the fertilizer is evenly distributed and absorbed well with the soil, so that plants can grow optimally.

Fig. 6 Implementation of Tool Testing with Partners

This image shows the implementation of testing a drip-based irrigation tool IoT with solar panels with Teknopark partners, represented by Mr. Agus Maulana. In this picture, Mr Agus Maulana is checking and ensuring that the irrigation system is functioning properly. This testing is purposeful to validate tool performance in actual field conditions, as well ensure that all components work according to specified specifications set. This tool is equipped with a solar panel which is an energy source, ensure that the irrigation system can operate independently and efficiently.

Partner participation in this testing is critical to gain direct feedback and identify potential improvements. Collaboration with Teknopark and Mr. Agus Maulana helped in adapting the technology with real needs in the field, ensuring that this tool can deliver maximum benefit for farmers. With field testing, irrigation systems These drops are expected to increase the efficiency of water and resource use energy, as well as supporting more sustainable agriculture.

4. Conclusions

IoT based drip irrigation with solar panels offers a variety advantages compared to conventional drip irrigation. One of the advantages The main issue is water use efficiency. Conventional irrigation often relies on manual settings or simple timers that are less responsive to the actual condition of the soil, so there tends to be a waste of water. In contrast, IoT-based irrigation uses soil moisture sensors that can controls irrigation automatically, adapting to plant needs in real-time, and reduce water waste. In addition, energy resources the ones used are also more sustainable. If conventional irrigation relies on electricity from the public grid, IoT-based irrigation relies on solar panels, which reducing dependence on conventional energy and making the system more efficient environmentally friendly.

In terms of control and monitoring, conventional drip irrigation requires Manual intervention is time consuming and has a high risk of error man. On the other hand, IoT-based irrigation allows farmers to monitor and control irrigation remotely via web application, with data realtime and notifications that help in making better decisions appropriate. This not only improves operational efficiency but also reduce long-term costs. Overall, drip irrigation is IoT based with solar panels is a more modern, efficient and sustainable solution, which supports more environmentally friendly and energy efficient agriculture.

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